

The Atmospheric Interface in CESM

Jennifer Kay, David Bailey

National Center for Atmospheric Research

Elizabeth Hunke

Los Alamos National Laboratory

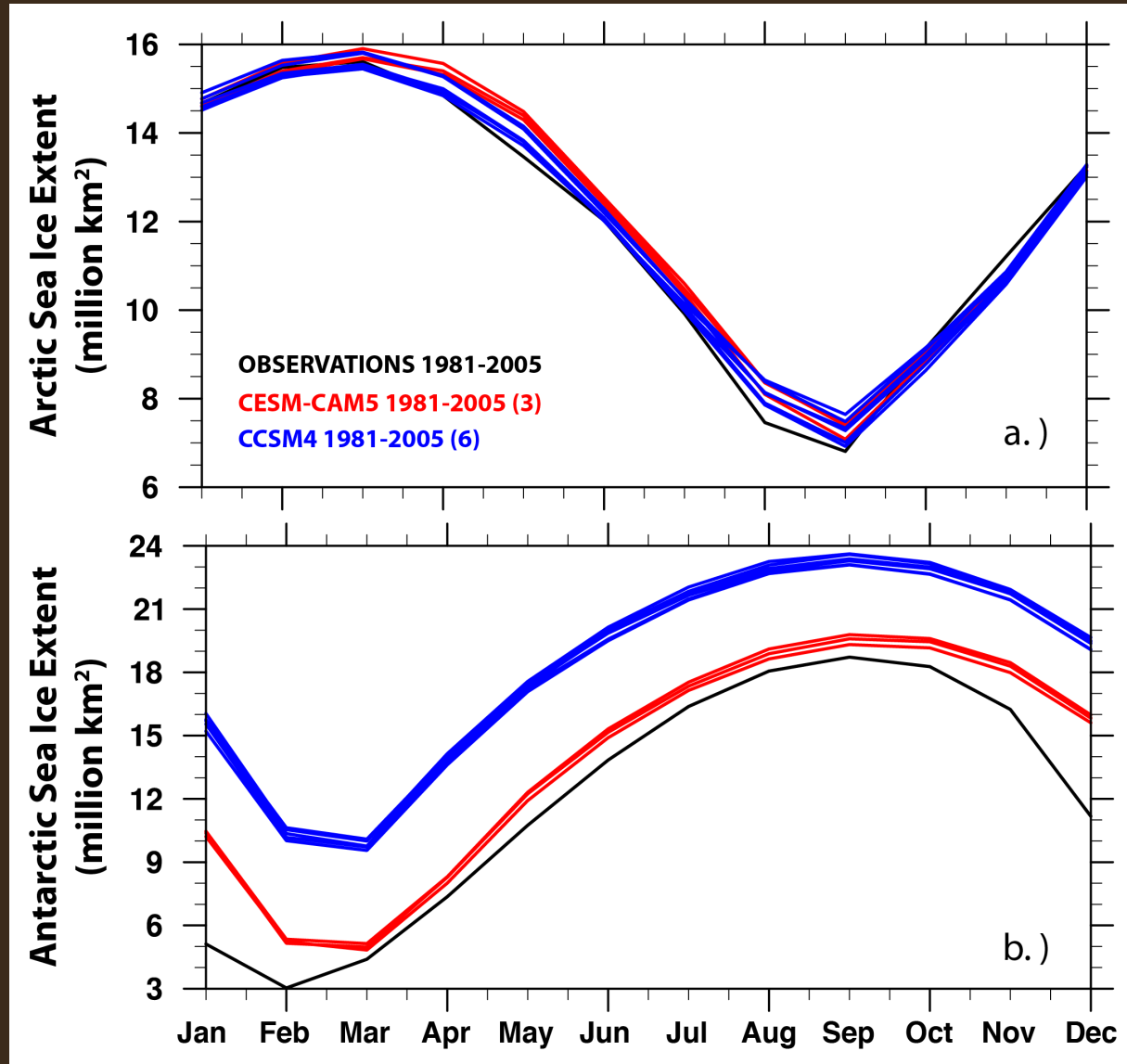


Atmospheric Model (CAM) Physics

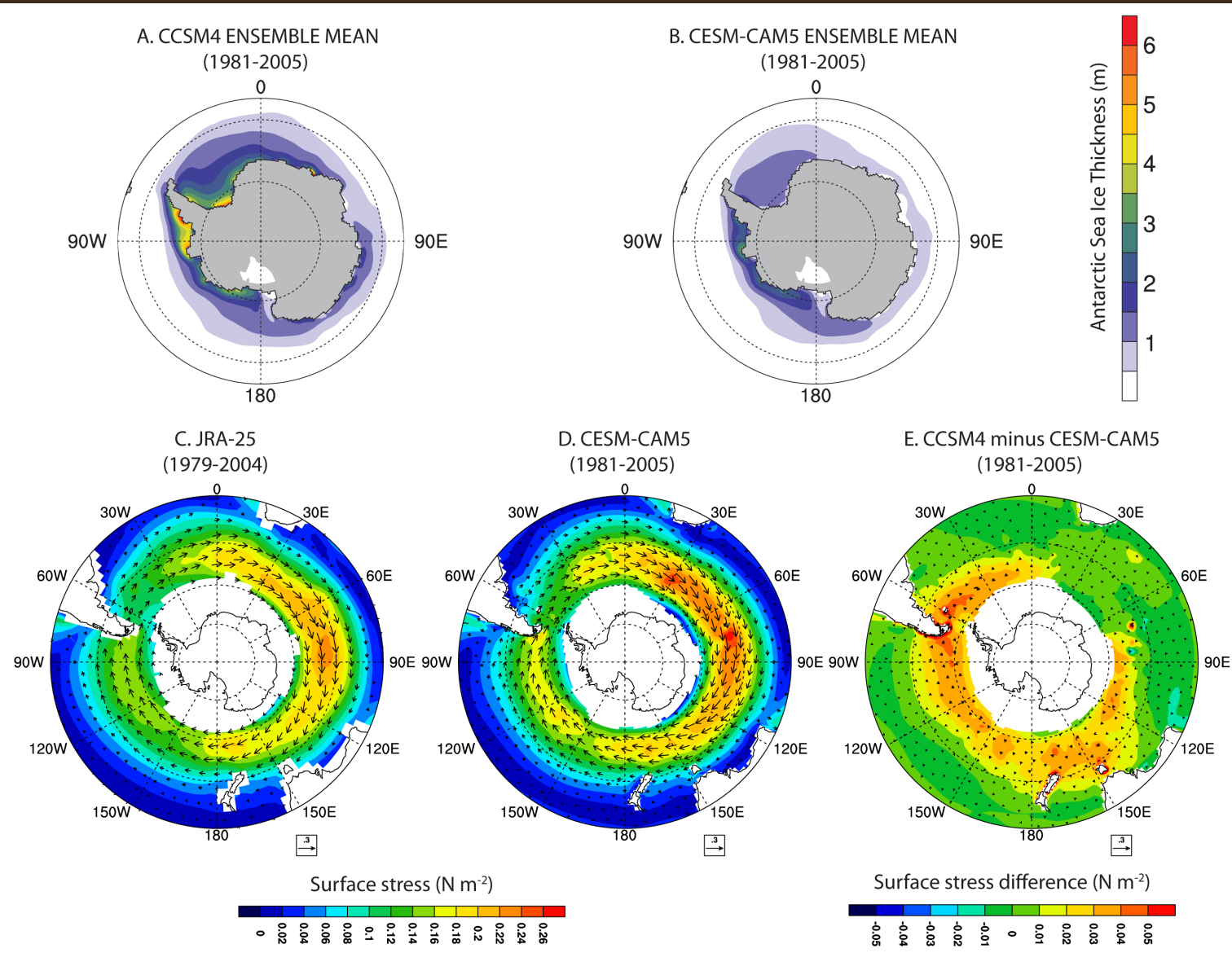
	CAM5 (Neale et al, 2011a) Released in June 2010, 30 vertical levels	CAM4 (Neale et al, 2011b) Released in April 2010, 26 vertical levels
Radiation	RRTMG (Iacono et al. 2008)	CAMRT (Collins et al. 2001)
Shallow Convection	Mass flux scheme with CIN closure (Park and Bretherton 2009)	3-level adjustment of moist static energy (Hack 1994)
Deep Convection	Bulk mass flux with CAPE closure (Neale et al. 2008)	Bulk mass flux with CAPE closure (Neale et al. 2008)
Planetary boundary layer and turbulence	Moist turbulence scheme based on diagnostic TKE (Bretherton and Park 2009)	Dry turbulence scheme based on specified K profile (Holtslag and Boville 1993)
Cloud microphysics and macrophysics	Prognostic double moment microphysics (Morrison and Gettelman 2008) with ice supersaturation (Gettelman et al 2010), diagnostic precipitation at each model level, and diagnostic cloud fraction scheme	Prognostic single moment microphysics, diagnostic precipitation at surface, and diagnostic cloud fraction (Rasch and Kristjansson 1998)
Aerosols	Modal aerosol model (Liu et al. 2011)	Bulk aerosol model

Improved CAM physics have had a large influence on CESM simulations in the polar regions!

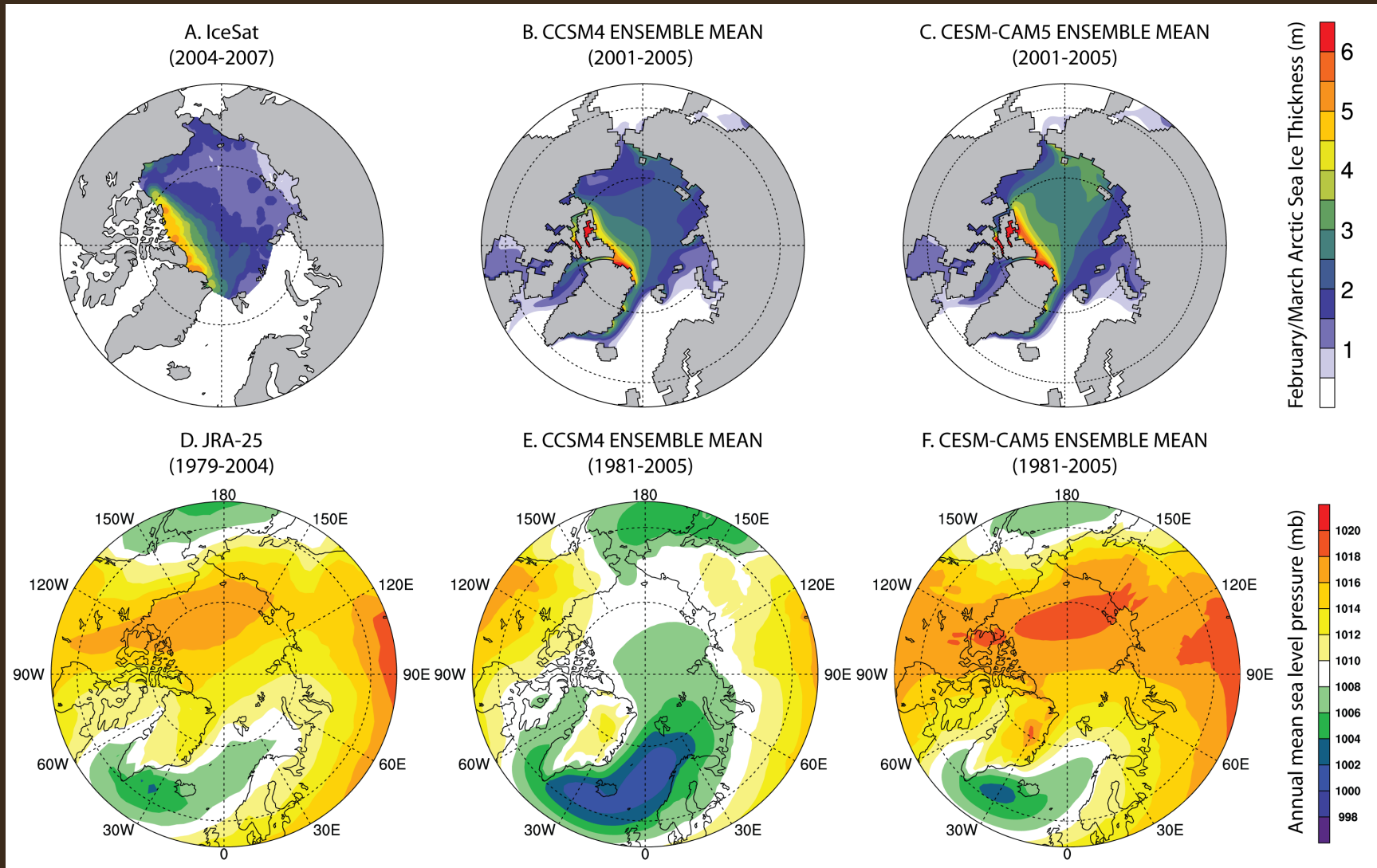
Late 20th century sea ice extent



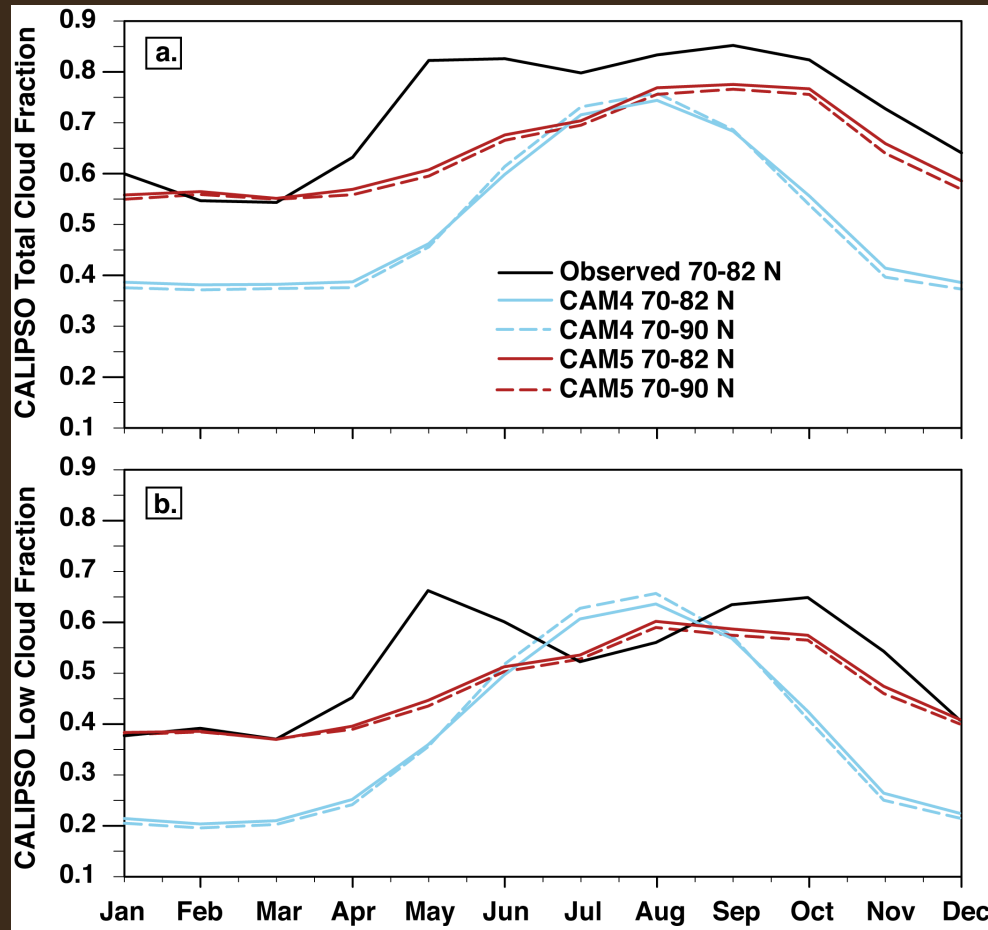
Antarctic Sea Ice in CESM



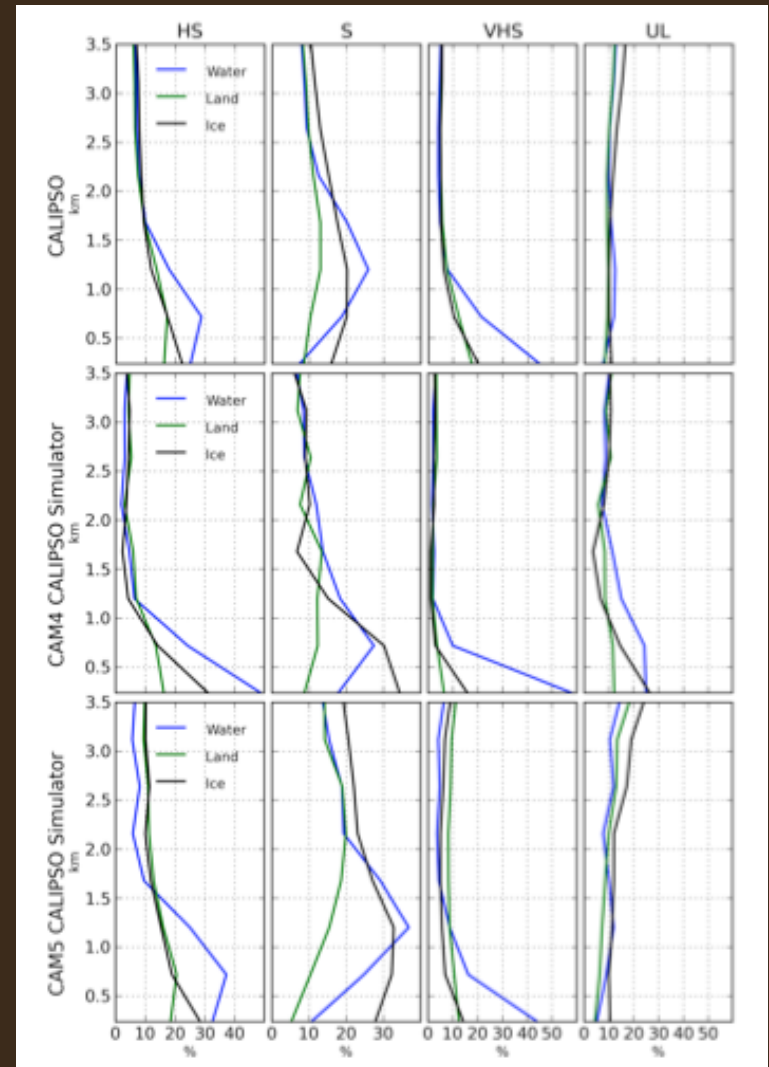
CESM Arctic sea ice and atmospheric circulation



COSP-enabled Arctic cloud fraction comparisons show improvement from CAM4 to CAM5



Kay, Hillman, Klein, Zhang, Medeiros, Gettelman, Pincus, Eaton, Boyle, Marchand and Ackerman, *J. Climate CESM Special Issue* (2012)

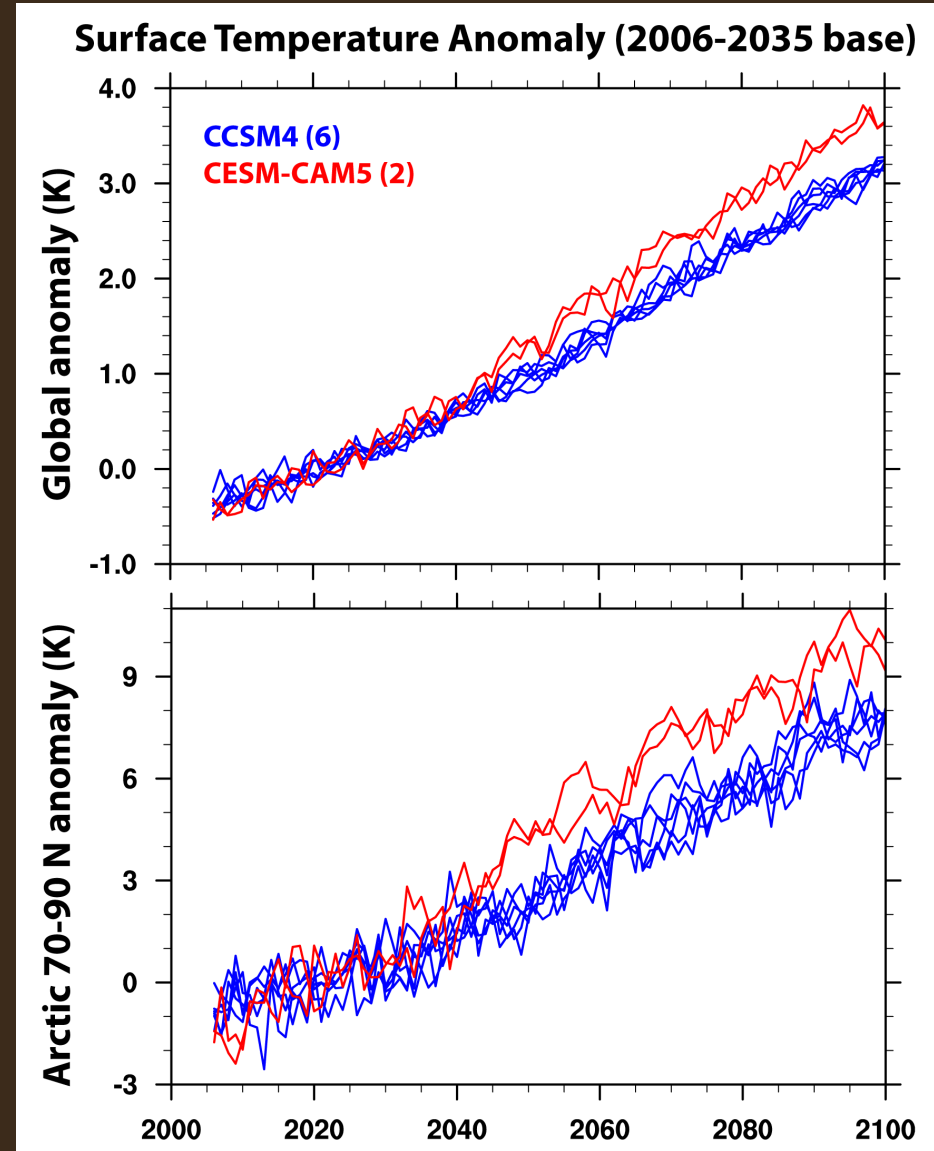


Barton et al., *JGR* (in press)

CESM 21st century surface warming (RCP8.5)

CESM-CAM5 warms more than CCSM4 by the mid-late 21st century, both globally and in the Arctic.

(RCP8.5 similar to 2xCO₂)



Equilibrium Arctic response to $2\times\text{CO}_2$

Positive
feedbacks
enhance
greenhouse
warming.

Feedback strength ($\text{Wm}^{-2} \text{K}^{-1}$)

Negative
feedbacks
oppose
greenhouse
warming.

3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0

CAM4: Arctic warming +7.0 K, climate sensitivity 3.1 K
CAM5: Arctic warming +10.2 K, climate sensitivity 4.0 K

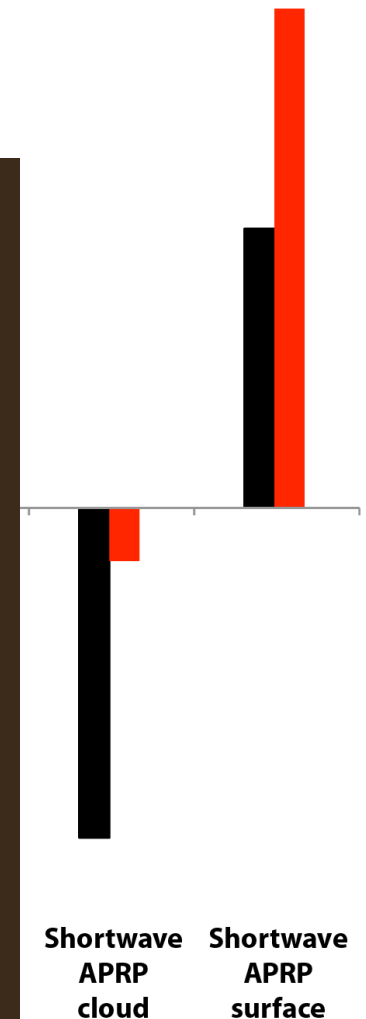
**What explains the
greater Arctic
warming in
CAM5?**



**Larger $2\times\text{CO}_2$ forcing
(no tropospheric response)**

Less negative shortwave cloud feedbacks

**More positive surface albedo feedbacks
(due to optically thinner clouds)**



A Few Nuts and Bolts

How does the surface interface work in CESM?



Barrow

A CESM column at the surface interface

... up to 2 mb (30 levels)

~900 mb (~ 820 m)

atmosphere (CAM)

~925 mb (~ 610 m)

~947 mb (~ 425 m)

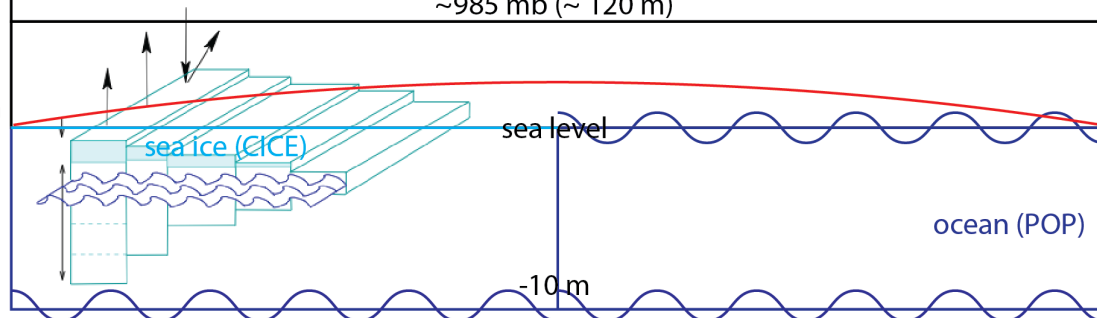
~967 mb (~ 262 m)

~985 mb (~ 120 m)

atmospheric boundary
layer (ABL) coupling
in CAM with
area-weighted
10 m surface values

surface coupling
in CICE for each
ice thickness category

10 m



10 m

surface coupling
in CESM coupler
(CPL)

Which fields are coupled?

CAM → CICE

Temperature, humidity, winds, radiation, precipitation, aerosols...

(z, ptem, tbot, shum, dens, sw components, lw, rain, snow)

CICE → CAM

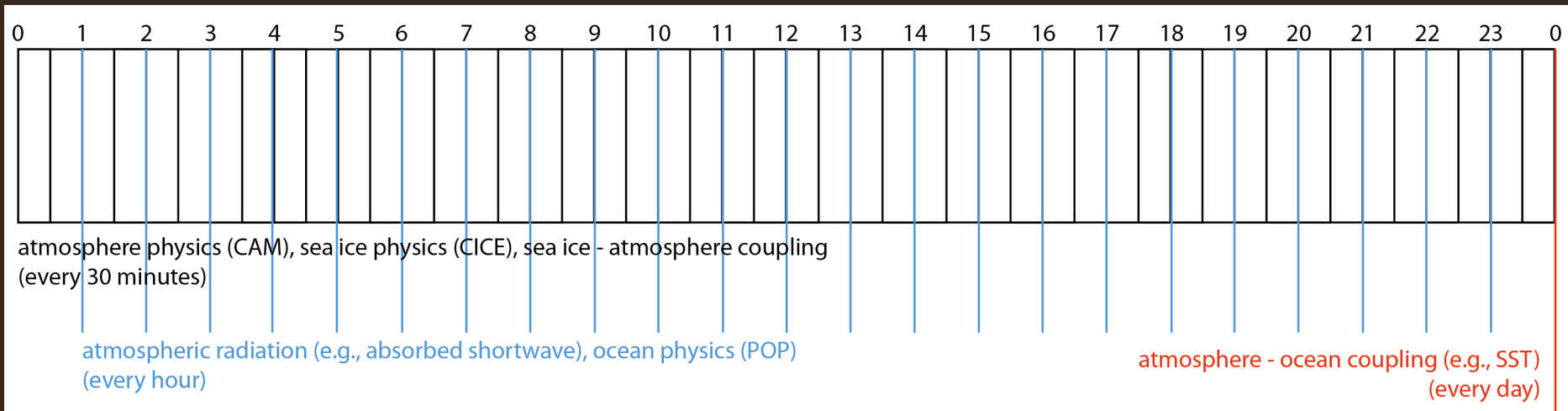
Surface albedo, surface fluxes and stresses

(ifrac, tsrf, albedo components, u10, tref, qref, snowh (last four are diagnostics for history), tau_ai, flat, fsens, flwout, evap, fswabs)

CAM ↔ POP

Surface calculations done in the coupler

A day at the surface interface in CESM



A satellite image of a polar region, likely the Arctic, showing a vast expanse of white ice and snow. A small red dot is visible on the lower left side of the image, marking the location of Barrow. The text "Barrow" is written in red below the dot.

What is absent in the CESM framework?

What are the most critical resolution/coupling issues for credible climate simulations?

Discuss.



Barrow